



ABSciCON 2017

MESA, ARIZONA

1
00:00:12,250 --> 00:00:06,150

you

2
00:00:18,340 --> 00:00:14,010

[Music]

3
00:00:19,540 --> 00:00:18,350

thank you for coming to my talk so my

4
00:00:21,910 --> 00:00:19,550

system is a little bit different we've

5
00:00:23,740 --> 00:00:21,920

been hearing about a lot about hot

6
00:00:26,260 --> 00:00:23,750

spring systems and so this is a

7
00:00:28,240 --> 00:00:26,270

terrestrial weathering system so I would

8
00:00:31,540 --> 00:00:28,250

just like to start out by framing this

9
00:00:34,810 --> 00:00:31,550

in astrobiological context so this

10
00:00:36,580 --> 00:00:34,820

classic paper here basically did free

11
00:00:38,799 --> 00:00:36,590

energy calculations for the weathering

12
00:00:41,799 --> 00:00:38,809

of iron-bearing silicate minerals such

13
00:00:43,810 --> 00:00:41,809

as Bay Li or Pharaoh silly and you

14

00:00:45,790 --> 00:00:43,820

actually could have based on this the

15

00:00:48,130 --> 00:00:45,800

free energy of these reactions alone

16

00:00:50,319 --> 00:00:48,140

produce an estimated 20 grams per cubic

17

00:00:53,410 --> 00:00:50,329

centimeter of biota over Martian history

18

00:00:55,750 --> 00:00:53,420

and while that is you know less than you

19

00:00:58,350 --> 00:00:55,760

would predict basic first photo trophy

20

00:01:03,639 --> 00:00:58,360

it's also not entirely inconsequential

21

00:01:04,329 --> 00:01:03,649

so press it like you mean it they

22

00:01:07,779 --> 00:01:04,339

weren't lying

23

00:01:10,240 --> 00:01:07,789

oh so so we also know that microbes are

24

00:01:11,590 --> 00:01:10,250

able to directly access the iron that is

25

00:01:14,260 --> 00:01:11,600

found in the silicate mineral lattice

26
00:01:17,830 --> 00:01:14,270
for an energy metabolism and this was

27
00:01:19,270 --> 00:01:17,840
demonstrated very beautifully by my

28
00:01:23,140 --> 00:01:19,280
advisors lab group prior to my arrival

29
00:01:25,179 --> 00:01:23,150
at UW and what they showed was the

30
00:01:27,580 --> 00:01:25,189
microbial left the trophic oxidation of

31
00:01:29,950 --> 00:01:27,590
the structural iron in bio type so that

32
00:01:31,570 --> 00:01:29,960
was the intent by current tracking the

33
00:01:34,120 --> 00:01:31,580
in growth of cells coupled to the

34
00:01:36,130 --> 00:01:34,130
oxidation of iron as well as consumption

35
00:01:38,130 --> 00:01:36,140
this was done under nitrate reducing

36
00:01:42,160 --> 00:01:38,140
condition so this is also coupled to the

37
00:01:43,569 --> 00:01:42,170
the decrease in nitrate but what was

38
00:01:45,190 --> 00:01:43,579

really elegant about this study was the

39

00:01:47,590 --> 00:01:45,200

actual demonstration of what's going on

40

00:01:49,510 --> 00:01:47,600

with the mineralogy so there was also

41

00:01:51,880 --> 00:01:49,520

this all this beautiful microscopy and

42

00:01:53,469 --> 00:01:51,890

spectroscopy that went into this and one

43

00:01:55,480 --> 00:01:53,479

of the interesting things that you see

44

00:01:58,569 --> 00:01:55,490

is actually the expulsion of iron oxide

45

00:02:00,429 --> 00:01:58,579

nanoparticles from the bio type um from

46

00:02:03,999 --> 00:02:00,439

the bio tight structure and that could

47

00:02:09,780 --> 00:02:04,009

be a result of the charge imbalance and

48

00:02:12,370 --> 00:02:09,790

then subsequent expulsion of of that so

49

00:02:14,289 --> 00:02:12,380

putting all of those things together the

50

00:02:16,390 --> 00:02:14,299

proposed mechanism or proposed model of

51
00:02:18,250 --> 00:02:16,400
this was a direct enzymatic attack on

52
00:02:22,720 --> 00:02:18,260
the mineral surface and that's in

53
00:02:24,900 --> 00:02:22,730
contrast to a a abiotic dissolution

54
00:02:27,540 --> 00:02:24,910
process whereby you would have an iron

55
00:02:29,820 --> 00:02:27,550
moving into solution and then subsequent

56
00:02:31,950 --> 00:02:29,830
utilization of that so this was proposed

57
00:02:35,250 --> 00:02:31,960
to be a direct enzymatic attack mediated

58
00:02:37,470 --> 00:02:35,260
by wrong button mediated by outer

59
00:02:40,110 --> 00:02:37,480
membrane proteins and we will get into

60
00:02:41,760 --> 00:02:40,120
those a little bit later so I wanted to

61
00:02:44,940 --> 00:02:41,770
take this to the field I want to define

62
00:02:47,070 --> 00:02:44,950
an environment of perhaps where a

63
00:02:50,580 --> 00:02:47,080

process like this would be would be

64

00:02:52,110 --> 00:02:50,590

relevant so humor me for just one second

65

00:02:55,260 --> 00:02:52,120

I am not about to tell you that I think

66

00:02:59,130 --> 00:02:55,270

Mars is made of granite diorite however

67

00:03:01,830 --> 00:02:59,140

this is the rio blanco quartz i write of

68

00:03:04,290 --> 00:03:01,840

the wiki amount ins in Puerto Rico so

69

00:03:07,590 --> 00:03:04,300

this is a extremely rapidly weathering

70

00:03:10,350 --> 00:03:07,600

granitic system but we have what we have

71

00:03:11,970 --> 00:03:10,360

is appreciable weight for sense of the

72

00:03:14,640 --> 00:03:11,980

iron-bearing minerals biotite and

73

00:03:17,010 --> 00:03:14,650

hornblende and so this is a picture of

74

00:03:18,900 --> 00:03:17,020

it that was exposed by a landslide and

75

00:03:20,580 --> 00:03:18,910

you see this beautiful Serota weathered

76
00:03:23,160 --> 00:03:20,590
weathering pattern that is very typical

77
00:03:26,280 --> 00:03:23,170
for a granite and what's driving this

78
00:03:28,350 --> 00:03:26,290
coincident coincidentally enough you

79
00:03:30,510 --> 00:03:28,360
know this weathering pattern is actually

80
00:03:32,850 --> 00:03:30,520
the first step in the weathering is the

81
00:03:36,570 --> 00:03:32,860
oxidation of the structural iron in the

82
00:03:39,600 --> 00:03:36,580
mineral bio type convenient so this is

83
00:03:42,630 --> 00:03:39,610
weathering very very rapidly even for a

84
00:03:44,940 --> 00:03:42,640
granitic system and so there's also

85
00:03:48,810 --> 00:03:44,950
evidence based on this paper from

86
00:03:52,620 --> 00:03:48,820
heather bus 2005 at all i'm sorry the

87
00:03:54,750 --> 00:03:52,630
rest of you that there may be less a

88
00:03:56,700 --> 00:03:54,760

trophy involved here i don't have time

89

00:03:58,290 --> 00:03:56,710

to go over it but there's a really

90

00:04:02,070 --> 00:03:58,300

beautiful reactive transport model

91

00:04:04,110 --> 00:04:02,080

coupling the the availability of iron to

92

00:04:06,030 --> 00:04:04,120

the to the in growth of cells but what's

93

00:04:07,650 --> 00:04:06,040

interesting to note here is that where

94

00:04:09,600 --> 00:04:07,660

you have high concentrations of

95

00:04:12,450 --> 00:04:09,610

extractable ferrous iron you also have

96

00:04:15,590 --> 00:04:12,460

high concentrations of cells based on

97

00:04:20,880 --> 00:04:15,600

both direct counts and extractable DNA

98

00:04:23,040 --> 00:04:20,890

so we set out oh nope sorry

99

00:04:25,710 --> 00:04:23,050

so consensually you can think about it

100

00:04:27,390 --> 00:04:25,720

like this so here is a core stone that's

101
00:04:29,100 --> 00:04:27,400
been exposed by a road cut and if you

102
00:04:31,620 --> 00:04:29,110
know anything about geologists it's that

103
00:04:32,850 --> 00:04:31,630
we love road cuts because otherwise you

104
00:04:36,060 --> 00:04:32,860
wouldn't be able to see something like

105
00:04:37,470 --> 00:04:36,070
this so this conceptual model would

106
00:04:40,530 --> 00:04:37,480
actually be taking place at

107
00:04:42,750 --> 00:04:40,540
they between 5 to 8 meters depth and so

108
00:04:44,850 --> 00:04:42,760
you have an altered bedrock which looks

109
00:04:47,310 --> 00:04:44,860
like this and on top of that you have

110
00:04:48,810 --> 00:04:47,320
those those that that kind of onion skin

111
00:04:50,430 --> 00:04:48,820
peeling structure term the rhineland

112
00:04:52,350 --> 00:04:50,440
zone and that's where all of your

113
00:04:54,270 --> 00:04:52,360

pleasure places in your the hornblende

114

00:04:56,700 --> 00:04:54,280

weathers out and does not persist in the

115

00:04:58,590 --> 00:04:56,710

overlying Sacre light and the satellite

116

00:05:01,500 --> 00:04:58,600

is variable in thickness here between 5

117

00:05:03,540 --> 00:05:01,510

& 8 meters so the idea is you have a

118

00:05:06,360 --> 00:05:03,550

heterotrophic Li dominated community at

119

00:05:08,970 --> 00:05:06,370

depths in your surface soil and then you

120

00:05:11,070 --> 00:05:08,980

have where those high cell densities are

121

00:05:13,520 --> 00:05:11,080

again a chemo little autotrophic Li

122

00:05:17,790 --> 00:05:13,530

dominated community that is driven by

123

00:05:20,070 --> 00:05:17,800

the oxidation of iron in iron in the

124

00:05:22,520 --> 00:05:20,080

silicate mineral an interaction with a

125

00:05:25,020 --> 00:05:22,530

direct outer membrane protein or a

126
00:05:27,090 --> 00:05:25,030
direct enzymatic attack so this is the

127
00:05:28,890 --> 00:05:27,100
idea that through this process these

128
00:05:34,980 --> 00:05:28,900
microbes are playing a direct role in

129
00:05:37,890 --> 00:05:34,990
the conversion of rock to regolith okay

130
00:05:38,550 --> 00:05:37,900
so in June of last year I went to Puerto

131
00:05:41,640 --> 00:05:38,560
Rico

132
00:05:43,830 --> 00:05:41,650
and did some sampling we hand or hand

133
00:05:45,960 --> 00:05:43,840
augered three cores to the depths of

134
00:05:48,240 --> 00:05:45,970
auger refusal which was taken to be the

135
00:05:52,530 --> 00:05:48,250
bedrock satellite interface and the

136
00:05:55,650 --> 00:05:52,540
deepest point was 700 yes 785

137
00:05:58,500 --> 00:05:55,660
centimeters and we collected samples

138
00:06:02,130 --> 00:05:58,510

down at the satellite profile for

139

00:06:05,130 --> 00:06:02,140

microbiological and genomic analyses and

140

00:06:10,740 --> 00:06:05,140

this is you know how it how it looks

141

00:06:13,500 --> 00:06:10,750

like or what it looks like all right so

142

00:06:15,270 --> 00:06:13,510

just to kind of retrace what Heather did

143

00:06:18,390 --> 00:06:15,280

I actually wanted to know are b-cells

144

00:06:20,700 --> 00:06:18,400

active right do we just have dead

145

00:06:22,560 --> 00:06:20,710

dormant cells accumulating at the

146

00:06:24,770 --> 00:06:22,570

bedrock satellite interface and to

147

00:06:28,110 --> 00:06:24,780

answer that question then we did a TV

148

00:06:29,850 --> 00:06:28,120

bioluminescence assay measuring the ATP

149

00:06:32,130 --> 00:06:29,860

and if you remember anything from high

150

00:06:35,400 --> 00:06:32,140

school biology it's probably that ATP is

151

00:06:37,560 --> 00:06:35,410

the energy currency of the cell so I

152

00:06:39,630 --> 00:06:37,570

think is a beautiful diagram where you

153

00:06:41,880 --> 00:06:39,640

have high concentrations of Fe total

154

00:06:44,970 --> 00:06:41,890

iron total and that's by dilute HCl

155

00:06:47,640 --> 00:06:44,980

extract attends to the ATP tends to

156

00:06:50,070 --> 00:06:47,650

track that very very nicely so this is

157

00:06:51,540 --> 00:06:50,080

great to see not only do we have

158

00:06:53,550 --> 00:06:51,550

you know increased cell

159

00:06:58,379 --> 00:06:53,560

just by direct count but these cells

160

00:07:00,480 --> 00:06:58,389

actually appear to be active I also

161

00:07:04,200 --> 00:07:00,490

established enrichment cultures for

162

00:07:09,840 --> 00:07:04,210

these using the whole rock granodiorite

163

00:07:14,159 --> 00:07:09,850

or the constitutive minerals of inert

164

00:07:17,040 --> 00:07:14,169

again and again called that one so

165

00:07:18,990 --> 00:07:17,050

hornblende biotite and then also the

166

00:07:23,159 --> 00:07:19,000

other major phases being all by in

167

00:07:25,469 --> 00:07:23,169

quartz so so they got rocks they got

168

00:07:30,000 --> 00:07:25,479

groundwater and they got carbon dioxide

169

00:07:33,330 --> 00:07:30,010

and then we track them with overtime and

170

00:07:35,240 --> 00:07:33,340

for simplicity and for brevity I will

171

00:07:37,980 --> 00:07:35,250

only talk about the dire right

172

00:07:39,510 --> 00:07:37,990

enrichment cultures because this is home

173

00:07:43,650 --> 00:07:39,520

cooking to these microbes it's their

174

00:07:47,730 --> 00:07:43,660

actual native environment so what you've

175

00:07:49,909 --> 00:07:47,740

seen with time is after or so we're out

176

00:07:51,840 --> 00:07:49,919

to 172 days these are still ongoing

177

00:07:54,570 --> 00:07:51,850

they're not done yet I should probably

178

00:07:56,850 --> 00:07:54,580

sample them again is that in two of the

179

00:07:59,010 --> 00:07:56,860

two of the sexes a and B so the a B and

180

00:08:01,020 --> 00:07:59,020

C correspond to the material collected

181

00:08:01,500 --> 00:08:01,030

from the bottom of the three separate

182

00:08:03,629 --> 00:08:01,510

holes

183

00:08:06,779 --> 00:08:03,639

it appears that there is actually acts

184

00:08:09,000 --> 00:08:06,789

addition as measured by the FE 2 to Fe

185

00:08:11,219 --> 00:08:09,010

total ratio and then there also appears

186

00:08:13,350 --> 00:08:11,229

to be the generation of ATP in these

187

00:08:15,510 --> 00:08:13,360

cell cultures so it looks like you have

188

00:08:21,810 --> 00:08:15,520

the generation of ATP coupled to the

189

00:08:23,969 --> 00:08:21,820

oxidation of iron in the rack so this

190

00:08:27,719 --> 00:08:23,979

now moving on into a little bit of

191

00:08:28,890 --> 00:08:27,729

metagenomics so you may be tired of

192

00:08:30,900 --> 00:08:28,900

hearing or office systems already

193

00:08:33,540 --> 00:08:30,910

however these are really important

194

00:08:36,029 --> 00:08:33,550

systems before for licit OFI these extra

195

00:08:39,300 --> 00:08:36,039

cellular electron transport reactions so

196

00:08:41,040 --> 00:08:39,310

in the last top nathan spoke about this

197

00:08:43,649 --> 00:08:41,050

more about this type of system the poor

198

00:08:45,750 --> 00:08:43,659

and cytochrome system whereas i'm going

199

00:08:47,519 --> 00:08:45,760

to talk or focus more on these side c2

200

00:08:49,710 --> 00:08:47,529

type systems because that's what seems

201
00:08:51,300 --> 00:08:49,720
to be abundant here so the model

202
00:08:53,460 --> 00:08:51,310
organism for this is the civvies io

203
00:08:55,980 --> 00:08:53,470
bacillus farrell oxidant and what you

204
00:08:59,819 --> 00:08:55,990
have is the the membrane soluble protein

205
00:09:02,430 --> 00:08:59,829
that then is embedded itself no need for

206
00:09:04,650 --> 00:09:02,440
an extra pourraient and you have you

207
00:09:06,450 --> 00:09:04,660
know that oxidation of the

208
00:09:08,280 --> 00:09:06,460
and then the electrons are transferred

209
00:09:12,900 --> 00:09:08,290
to a carry plasmic either another

210
00:09:18,920 --> 00:09:12,910
cytochrome or in or some other electron

211
00:09:22,260 --> 00:09:18,930
carrier in the period plasm so in my

212
00:09:24,840 --> 00:09:22,270
metagenomic analysis I found I see two

213
00:09:29,460 --> 00:09:24,850

homologues several several of them and

214

00:09:31,080 --> 00:09:29,470

so probably so this is fine seven seven

215

00:09:34,980 --> 00:09:31,090

of the top twelve taxa actually have a

216

00:09:37,260 --> 00:09:34,990

homolog to decide to and so up top these

217

00:09:39,480 --> 00:09:37,270

are gene maps the model organism is a

218

00:09:44,040 --> 00:09:39,490

city thio bacillus arrow accident and

219

00:09:46,230 --> 00:09:44,050

the brown is the actual size situ and on

220

00:09:48,330 --> 00:09:46,240

the end terminus here is the number of

221

00:09:50,250 --> 00:09:48,340

heme binding motifs and on the

222

00:09:53,010 --> 00:09:50,260

c-terminus here is the number of

223

00:09:54,870 --> 00:09:53,020

transmembrane domains and in a city thio

224

00:09:58,140 --> 00:09:54,880

bacillus arrow oxygens you see it's 1

225

00:10:00,630 --> 00:09:58,150

and 18 and then next to that you will

226

00:10:03,080 --> 00:10:00,640

find a Oh apparently I'm missing a

227

00:10:06,480 --> 00:10:03,090

number there's a human a motif in this

228

00:10:08,520 --> 00:10:06,490

peri-peri plasmic cytochrome so next to

229

00:10:12,450 --> 00:10:08,530

that you have a periplasmic cytochrome

230

00:10:14,730 --> 00:10:12,460

to receive electrons from from this IC 2

231

00:10:17,280 --> 00:10:14,740

and so all of these these first side

232

00:10:20,220 --> 00:10:17,290

here are beta proteobacteria these are

233

00:10:23,520 --> 00:10:20,230

not particularly canonical iron

234

00:10:25,370 --> 00:10:23,530

oxidizers however it's not you know

235

00:10:27,630 --> 00:10:25,380

entirely unreasonable to expect

236

00:10:29,730 --> 00:10:27,640

something like this particularly in a

237

00:10:32,070 --> 00:10:29,740

Cooper avetis there's known other an

238

00:10:34,640 --> 00:10:32,080

oxidizing to previous taxa what's

239

00:10:37,100 --> 00:10:34,650

actually interesting to me here is these

240

00:10:41,700 --> 00:10:37,110

Xiamen Simona de CA they're gamma

241

00:10:44,430 --> 00:10:41,710

proteobacteria and in this case you know

242

00:10:46,470 --> 00:10:44,440

it has the periplasmic cytochrome but it

243

00:10:48,750 --> 00:10:46,480

also in another case has a rather than a

244

00:10:50,820 --> 00:10:48,760

cytochrome a high potential iron sulfur

245

00:10:54,660 --> 00:10:50,830

cluster and we also see that in one of

246

00:10:57,150 --> 00:10:54,670

these kibriya Vettes strains so to quote

247

00:10:59,310 --> 00:10:57,160

my advisor who quoted or to quote nathan

248

00:11:01,560 --> 00:10:59,320

who quoted my adviser when you see real

249

00:11:03,750 --> 00:11:01,570

Bisco and eet together in one

250

00:11:05,940 --> 00:11:03,760

metagenomic then it's kind of a smoking

251

00:11:08,970 --> 00:11:05,950

gun for lift a lot of trophies and that

252

00:11:12,360 --> 00:11:08,980

it appears to be what we have here so

253

00:11:13,950 --> 00:11:12,370

just to wrap this up i would like to

254

00:11:17,109 --> 00:11:13,960

revisit this conceptual model that i

255

00:11:21,729 --> 00:11:17,119

laid out earlier so we have

256

00:11:25,869 --> 00:11:21,739

the rio blanco quartz died right on top

257

00:11:28,569 --> 00:11:25,879

of that we have the satellite and we've

258

00:11:30,879 --> 00:11:28,579

demonstrated that not only are there

259

00:11:32,799 --> 00:11:30,889

cells there but they're also active

260

00:11:36,609 --> 00:11:32,809

right so this is a good news we have a

261

00:11:40,749 --> 00:11:36,619

active microbial community institute and

262

00:11:43,089 --> 00:11:40,759

then also in enrichment culture we have

263

00:11:45,309 --> 00:11:43,099

demonstrated that there is a parent

264

00:11:48,489 --> 00:11:45,319

coupling of the oxidation of iron to the

265

00:11:50,139 --> 00:11:48,499

generation of ATP at but then the

266

00:11:52,509 --> 00:11:50,149

smoking gun in all of this was that

267

00:11:55,899 --> 00:11:52,519

interaction with these outer membrane

268

00:11:59,139 --> 00:11:55,909

proteins and well there you go

269

00:12:01,389 --> 00:11:59,149

we have cycie to homologues in a fairly

270

00:12:03,969 --> 00:12:01,399

considerable number of taxa within these

271

00:12:07,299 --> 00:12:03,979

within these and cultures so it does

272

00:12:09,759 --> 00:12:07,309

appear that this idea that rocks or

273

00:12:13,299 --> 00:12:09,769

regolith is catalyzed by bacteria does

274

00:12:16,449 --> 00:12:13,309

actually hold so i would just like to

275

00:12:18,159 --> 00:12:16,459

thank my collaborators as well as the

276

00:12:20,139 --> 00:12:18,169

u.s. Forest Service and the lukio

277

00:12:22,389 --> 00:12:20,149

critical zone Observatory for logistical

278

00:12:24,579 --> 00:12:22,399

help sampling these and then my funding

279

00:12:27,279 --> 00:12:24,589

sources the NAI and Department of

280

00:12:37,269 --> 00:12:27,289

Geoscience at UW Madison and I have time

281

00:12:44,979 --> 00:12:37,279

for some questions thanks Stephanie do

282

00:12:47,139 --> 00:12:44,989

we have any questions so I've got one so

283

00:12:49,149 --> 00:12:47,149

at what point in that sediment column

284

00:12:51,519 --> 00:12:49,159

does it go in aqsa can do do you find

285

00:12:53,979 --> 00:12:51,529

evidence it doesn't it does not know

286

00:12:56,849 --> 00:12:53,989

it's above the water table so this is up

287

00:13:06,819 --> 00:12:56,859

on a ridge it's not even subarctic

288

00:13:09,140 --> 00:13:06,829

okay any additional questions okay so